

Activated Carbon

Processing

Executive Summary

Activated carbon was petitioned to remove brown color from white grape juice concentrate. Carbon is obtained from a wide variety of sources and is activated by a number of different processes. While some of these carbon sources are agricultural, and several of the processes do not involve the use of substances that are prohibited in organic production and handling, the reviewers all considered activated carbon in general to be non-agricultural and synthetic. There are many different uses and applications for activated carbon in food processing. Most of these are related to the substance's ion exchange capacity. All of the reviewers advised that the NOSB recommend that the substance be added to the National List. All discussed extensively the need for restrictions and limitations, and the compatibility of the substance with organic handling principles. One proposed an annotation that would limit sources and processes; another proposed an annotation that would prohibit the petitioned use; and the third suggested that activated carbon be listed without annotation.

Summary of TAP Reviewer Analysis¹

95% organic

Form	Synthetic / Non-Synthetic:	Allowed or Prohibited:	Suggested Annotation:
205.605(b) Activated carbon	Synthetic (3-0)	Yes (3) No (0)	<ol style="list-style-type: none">1. As a processing aid only. Must meet Food Chemicals Codex purity requirement and be manufactured from agricultural products by steam activation.2. Processing Materials for filtering water, only. It should not be used to recreate / improve flavors, or colors of organically processed food.3. <i>None</i>

Made with organic (70% or more organic ingredients)

Form	Synthetic / Non-Synthetic:	Allowed or Prohibited:	Suggested Annotation:
205.605(b) Activated carbon	Synthetic (3-0)	Yes (3) No (0)	<i>None</i> (2) It should not be used to recreate/ improve flavors, or colors of organically processed food (1).

¹ This Technical Advisory Panel (TAP) review is based on the information available as of the date of this review. This review addresses the requirements of the Organic Foods Production Act to the best of the investigator's ability, and has been reviewed by experts on the TAP. The substance is evaluated against the criteria found in section 2119(m) of the OFPA [7 USC 6517(m)]. The information and advice presented to the NOSB is based on the technical evaluation against that criteria, and does not incorporate commercial availability, socio-economic impact, or other factors that the NOSB and the USDA may want to consider in making decisions.

Identification

Chemical Names:

Carbon, Activated

Other Name:

Activated charcoal; Active carbon; Active charcoal;
Amorphous carbon; Bone black; Bone coal; Channel
black; Charcoal; Decolorizing carbon; Lamp black

Trade Names:

ADP; APA; APC; BL; C; Calgon Type RB; Cane Cal;
Color Sorb; CPG; CPG LF; Diahope-S60; OL; PWA;
RC; SGL (Ash and Ash, 1995); Filtrasorb, Norit (Pataik,
1992);

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CAS Numbers:

7440-44-0; 64365-11-3

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Other Codes:

EINECS No.: 231-153-3

ECL Serial No.: KE-04671

Characterization

Composition:

Carbon arranged in a quasi-graphitic form in a small particle size.

Properties:

A solid, porous, black carbonaceous material. Tasteless (Budavari, 1996). Activated carbon is distinguished from elemental carbon by the removal of all non-carbon impurities and the oxidation of the carbon surface (Mattson and Mark, 1971).

How Made:

Activated carbon can be prepared from a large number of sources by a wide variety of methods. The Merck Index divides these into four basic forms: *Animal charcoal* is obtained by charring bones, meat, blood, etc.; *Gas black, furnace black, or channel black* is obtained by the incomplete combustion of natural gas; *Lamp black* is obtained by the burning various fats, oils, resins, etc., and *Activated charcoal* is prepared from wood and vegetables (Budavari, 1996).

Activated carbon can be produced from a number of agricultural commodities. Among these are hardwoods, grain hulls, corn cobs, and nut shells (Young, 1996). Steam activation can also be used with food-grade carbonaceous material (Burdock, 1997). Acid treatment is also common. For example, pecan shells can be activated by treatment with hydrochloric acid, then heated in an electric furnace for four hours at 800-1,000°C. in an atmosphere of carbon dioxide (Young, 1996).

There is some disagreement among various sources as to whether bone char or bone black should be considered an 'active carbon.' Mantell (1968) devotes an entire chapter to bone char, noting that it contains between 9-10% adsorbent carbon when prepared. Smíšek and Cerný (1970) dismiss bone char as a form of active carbon because it is predominately composed of calcium phosphate, and note that many of its properties—particularly its capacity to decolorize sugar and other sweeteners—are related to this heterogenous chemical composition. It is included in this review because of its historical and commercial importance to the food processing industry and to sugar refining in particular. Bone char is prepared by the removal of all flesh, fat, and oil. After its adsorptive capacity is spent, bone char can be mechanically and physically regenerated through drying and pricking with hot rods (Elmenhorst, 1880).

Among the other raw materials used as precursors to make activated carbon are sawdust, peat, lignite, coal, cellulose residues (Lambiotte, 1942), and petroleum coke, spent ion exchange resins such as styrene-divinyl benzene polymers (von Blucher and De Ruiter, 1999) and phenol-formaldehyde resins (Teng and Wang, 2000), and old automobile tires (Whitaker and Grindstaff, 1974; Sang, 1975; Watanabe and Miyajima, 1976; Teng, et al., 1999), and sewage sludge (Kemmer, Robertson, and Mattix, 1972; Nickerson and Messman, 1975; Sutherland, 1976; Khalili, et al., 2000). There are no published restrictions on sources for food-grade activated charcoal, only on the final product specifications (Food Chemicals Codex, 1996). Various binding agents may be added to improve the structure (Baker et al., 1992). Commercial sources appear to be made from a variety of precursors, activating agents, and binders (Tolles, et al, 1993; Ashford, 1994; Ivey and Hoffman, 1998).

Any given carbon sources may be prepared, treated, or manufactured by a wide variety of methods. These may or many not involve synthetic acids, bases, and other substances in a stream of activating gases such as steam (H₂O), nitrogen (N₂) or carbon dioxide (CO₂). Yields and quality can be improved by the removal of moisture (UN FAO, 1985). Microwaves can be used to pyrolyze the carbon source (Holland, 1994). Lignite and peat are made into activated charcoal by low-temperature charring, followed by treatment with either superheated steam or potassium hydroxide. Carbon can be made into a cation-exchange resin

by sulfonation, or by nitration and reduction. Treatment of low-rank coal with ethylene dichloride and ammonia makes activated carbon an anion exchange resin (Vorres, 1996). Some processes treat carbonaceous matter with phosphoric acid and / or zinc chloride (Krczil, 1937), with the resulting mixture carbonized at an elevated temperature, followed by the removal of the chemical activating agent by water washing (Food Chemicals Codex, 1996).

Activated carbon can be recycled, reactivated, or regenerated from spent activated carbon. Activated carbon used to treat hazardous waste could be considered to be hazardous waste itself (Shapiro, 1996).

Specific Uses:

Decolorizing agent; taste- and odor-removing agent; purification agent in food processing (Food Chemicals Codex, 1996). Food and beverage production accounts for only about 6% of the market for liquid-phase activated carbon (Baker, et al., 1992). Of this, the greatest use is decoloring sugar. More recent applications have enabled the production of xylose and its derivatives from complex cellulose sources via fermentation and activated charcoal (Mussatto and Roberto, 2001).

Activated carbon remains the most common method used to decolor vinegar (Achaerandio, et al., 2002). Activated carbon can also be used to remove ethylene from fruit storage facilities, particularly if brominated (Reid, 1985).

The primary use for activated carbon is the treatment of water, including potable water (24% of all use); wastewater (21%) and groundwater remediation (4%) which accounts for approximately half of all the use in the US (Baker et al., 1992).

These are indirectly related to organic production, because disinfected water used filtered through activated carbon is common a common food ingredient (Severn Trent, 2000). Non-agricultural ingredients—such as enzymes—are also often purified by the use of activated carbon (Aikat et al., 2001). Both can result in products processed by activated charcoal used to process food and beverages. Activated charcoal also has non-food uses related to the production and consumption of agricultural commodities. For example, activated charcoal is used to filter tobacco smoke. There are also a number of applications related to purification in the clothing, textile, personal care, cosmetics, and pharmaceutical industry.

Activated carbon also has a broad range of applications outside of food processing. Veterinary and analogous medical applications—such as detoxification—are the subject of a separate TAP review. Activated charcoal is used in agriculture as a soil amendment (e.g. alkali-treated humates and humic acid derivatives), and as a component of nursery or transplant media (Wellen, et al., 1999), as well as to remove pesticide residues (McCarty, 2002). Among the literally hundreds of other uses are agents in gas masks; pollution control devices such as car catalytic converters and flue gas desulfurization (Ashford, 1994).

Action:

Activated carbon has an extraordinarily large surface area and pore volume that gives it a unique adsorption capacity (Baker, et al., 1992). Commercial food grade products range between 300 and 2,000 m²/g (Burdock, 1997). Some have surface areas as high as 5,000 m²/g. The specific mode of action is extremely complex, and has been the subject of much study and debate. Activated carbon has both chemical and physical effects on substances where it is used as a treatment agent. Activity can be separated into (1) adsorption; (2) mechanical filtration; (3) ion exchange; and (4) surface oxidation.

Adsorption is the most studied of these properties in activated carbon. Most food processing applications of activated carbon can be characterized by the adsorption that occurs when components of a liquid (the food or beverage) attaches to a solid (activated carbon). This can be either physical or chemical in nature, and frequently involves both. Physical adsorption involves the attraction by electrical charge differences between the adsorbent and the adsorbate. Chemical adsorption is the product of a reaction between the adsorbent and the adsorbate.

Adsorption capacity depends on

- a) physical and chemical characteristics of the adsorbent (carbon);
- b) physical and chemical characteristics of the adsorbate (the food or beverage);
- c) concentration of the adsorbate in liquid solution;
- d) characteristics of the liquid phase (e.g. pH, temperature)
- e) amount of time the adsorbate is in contact with the adsorbent (residence time).

(Cheremisinoff and Morresi, 1978).

Mechanical filtration involves the physical separation of suspended solids from a liquid passing through carbon arrayed as a porous media in a column or bed. Any finely divided solid—such as sand or cellulose—can accomplish this. While this accounts for some of the clarification properties of carbon, it is seldom the sole reason for the selection of carbon as a clarification medium. The effectiveness of filtration depends on particle size, bulk density, and hardness (Ahmedna et al., 2000). While a smaller particle size results in a clearer liquid, it also slows the speed of processing. Bulk density determines

how much carbon can be contained in a given container. Hardness matters because the particles need to have sufficient strength to block the particulate matter being filtered.

Ion exchange is defined as a ‘reversible chemical reaction between a solid and an aqueous solution that allows the interchange of ions . . .’ (Ockerman, 1991). Coal is a natural ion exchanger (Helffrich, 1962). Ion exchange can be enhanced by chemical activation. Carbon surfaces have both negative (anionic) or positive (cationic) charges to attract free ions in solution or suspension, depending on how they are treated. Treatment of carbon with a base increases the capacity of carbon to exchange anions; acidulation of the surface makes carbon a powerful cation exchanger (Jankowska, et al. 1991).

Surface oxidation involves the chemisorption (=chemical adsorption) of atmospheric oxygen to the carbon and the further reaction of the surface oxides that chemically react with other substances that are oxidized. The surface of activated carbon has an electrical double layer (Mattson and Marks, 1971).

Combinations:

The purity of the carbon and other substances found with it depends on the source, the manufacturing process, whether it is a virgin or regenerated source, and formulation. Bone char is generally 9-10% carbon and about 90% ash, with 80% of bone char composed of calcium phosphates. Activated carbon can be combined with a number of other substances that are effective agents for ion exchange. These might include filtering aids—e.g. silicon dioxide—and resins. The carbon is usually packed in a column that is non-reactive, but sometimes columns and other packing material will also provide ion exchange activity. Some of these are ceramic (Kumuoka, 2002); or polymeric (Hughes and Bryan, 2002). Activated carbon may also be used with a variety of metal catalysts, including nickel, copper, palladium, ruthenium, and titanium. Chlorine is often used with activated carbon to remove phenols and other chemicals (Willey, 1976).

Carbon can be reused if the adsorbed substances are removed. This process is known as ‘regeneration.’ Simply heating the spent carbon at a given temperature for an adequate length of time can regenerate activated carbon to the point where it can be reused for tertiary wastewater treatment (thermal regeneration) (Mine Safety Appliance Corp., 1970). Thermal regeneration inevitably results in the loss of carbon (Battelle, 1970). Also, thermal methods may not be the most efficient, inexpensive, or reliable method, so a number of solvents, acids, and alkalis may be employed to remove the adsorbed substances. These include such things as carbon tetrachloride, hydrochloric acid, hydrogen peroxide, potassium hydroxide, sodium hydroxide (Mine Safety Research Corp., 1970). Optimization of the regeneration process depends on the substances adsorbed as well as the structure of the activated carbon.

Status

Historic Use:

Charcoal dates back to the prehistoric discovery of fire. Ancient Hindus filtered their water with charcoal (Cheremisinoff and Ellerbusch, 1978). Scheele discovered the fact that certain types of charcoal had adsorptive capacity—were chemically ‘active’—in 1773. Charcoal was found to decolor tartaric acid in 1785. In 1794, charcoal was first applied to the refinement of sugar (Jankowska, et al., 1991). Natural forms of activated carbon such as charred animal bones (bone black) were used to refine sugar (Derosne, 1845). Inventors patented a number of methods to improve the clarification, decolorization, and purification power of the bone char. These included improvements in the control of the heat of carbonization (Finken, 1863); differential oxidation (Chaney, 1924); mixing of bone with anthracite (Torstrick, 1868) or bitumenous (Wooster, 1924) coal; addition of calcium phosphate to carbonized sugar (Ray, 1929); the packing of various clays upon the bone char in the retorts (Kelsey, 1872); complexing with various binders (Morrell, 1935); acidulation (Lourens, 1931).

By 1901, scientists had developed ways to synthesize activated carbon from coal that had equivalent or superior adsorptive and decolorizing capacity to bone black (Smíšek, 1970). These methods were soon introduced to the US (Richter 1911). Use for removal of taste and odor from municipal water supplies in the US began about 1929 (Burdock, 1997).

OFPA, USDA Final Rule:

Activated carbon does not appear anywhere in the OFPA or NOP Final Rule. However, humic acid derivatives (7 CFR 205.601(j)(3)) are usually composed of alkali treated lignite coal, and can be thus be considered a form of activated carbon (Vorres, 1996).

Regulatory: EPA/NIEHS/Other Sources**USEPA:**

Activated carbon does not itself appear on any of the lists of hazardous substances (US EPA, 1998). However, given that it is used to remove toxic substances from potable water, wastewater treatment, and hazardous waste effluent, spent activated carbon contaminated with toxic substances removed from these production streams can be considered hazardous waste and fall under the EPA's authority under the Resource Conservation and Recovery Act's jurisdiction (40 CFR 264(x); Shapiro, 1996). For the most part, the regulations applied to food processors involve activated carbon as an effluent treatment system for wastewater (US EPA, 1998a).

Carbon is registered as an active pesticide ingredient (54 *Fed. Reg.* 7440; 54 *Fed. Reg.* 22706; 54 *Fed. Reg.* 30848; 54 *Fed. Reg.* 4388; 55 *Fed. Reg.* 31164) and is used as an inert ingredient in pesticides and appears on EPA Inerts List 4B (US EPA, 1995).

NIEHS: Does not appear in the National Toxicology Program database (NTP, 2002).

FDA: The only listing found in EAFUS for activated carbon (accessed July 12, 2002) is at 21 CFR 177.1210. This addresses substances for use as basic components of single and repeated use food contact surfaces. Specifically, activated carbon is permitted to form up to 1% of a closure with sealing gaskets for food containers. Activated carbon is also mentioned in the ion exchange section (21 CFR 173.25).

OSHA:

The Occupational Safety and Health Administration's OSHA Permissible Exposure Levels (PELs) for synthetic graphite (activated carbon) are:
(Total dust): 15 mg/m³
(Respirable fraction): 5 mg/m³
Source: 29 CFR 1910.1000.

DOT:

Activated carbon appears on the US Department of Transportation's Hazardous Materials Table because it is spontaneously combustible
Source: 59 *Fed. Reg.* 67395.

Status Among U.S. Certifiers

Not listed in any published standards. While the petitioner claims that it is allowed by at least one US certifier, the investigator was unable to find any documentary evidence to support that claim.

California Certified Organic Farmers (CCOF) – CCOF Manual Two: USDA Requirements For Organic Producers (Dec. 2001) not listed.

Oregon Tilth Certified Organic (OTCO) – Oregon Tilth Certified Organic Standards, Oct. 8, 2001. Not listed in Section 8, National List that accompanies the standards.

Organic Crop Improvement Association International (OCIA) OCIA Standards Manual NOP Standards plus OCIA International Requirements 2002: not listed

Quality Assurance International (QAI) – No reference.

Texas Department of Agriculture (TDA) Organic Certification Program – TDA Organic Certification Program Materials List (February 2000) not listed

Washington State Department of Agriculture (WSDA) Organic Food Program – Chapter 16-158-060 WAC (rev. January 18, 2001), not listed.

International

CODEX – Listed in Annex 2, Table 4 for use as a processing aid for the preparation of organic food without specific conditions.

EU 2092/91 – Listed in Annex VI, Section B for use as a processing aid for the preparation of organic food without specific conditions.

IFOAM – Listed in Appendix 4 for generally unrestricted use as a processing aid. (IFOAM IBS 2000)

Canada – (1999). Not listed in Appendix C, Permitted Substances for Processing.

Section 2119 OFPA U.S.C. 6518(m)(1-7) Criteria

1. *The potential of the substance for detrimental chemical interactions with other materials used in organic farming systems.*

As petitioned, activated charcoal used as a processing aid and additive would not have detrimental chemical interactions with other materials used in organic farming systems.

2. *The toxicity and mode of action of the substance and of its breakdown products or any contaminants, and their persistence and areas of concentration in the environment.*

Activated charcoal itself is regarded as an effective antidote to toxic substances, and is elemental in form. However, many applications will concentrate the toxic substances that it removes and captures, thus becoming toxic itself.

3. *The probability of environmental contamination during manufacture, use, misuse, or disposal of the substance.*

See Processing Criteria #2 below.

4. *The effects of the substance on human health.*

Can cause respiratory problems to those who handle it, especially as particle size decreases. Inhalation causes cough, trouble breathing, black sputum, and fibrosis (Patnaik, 1992). There is also a potential for it to spontaneously combust and incomplete combustion produces carbon monoxide (Cheremisinoff, 1999).

5. *The effects of the substance on biological and chemical interactions in the agroecosystem, including the physiological effects of the substance on soil organisms (including the salt index and solubility of the soil), crops and livestock.*

Use in processing generally does not have an effect or chemical interaction in the agroecosystem. See the humic acid derivatives TAP review for the impact of alkali treated coal on the soil. A separate review is being conducted for application in livestock production.

6. *The alternatives to using the substance in terms of practices or other available materials.*

See processing criteria #7 below.

7. *Its compatibility with a system of sustainable agriculture.*

See processing criteria #6.

Criteria From the February 10, 1999 NOSB Meeting

A PROCESSING AID OR ADJUVANT may be used if:

1. *It cannot be produced from a natural source and has no organic ingredients as substitutes.*

Activated carbon can be and is produced from a broad array of agricultural by-products (McElhinney, et al., 1942; UN FAO, 1985; Ahmedna, et al., 1997). Among the most effective and commercially viable sources are nut shells and fruit pits, such as coconut shells (Chaney, 1924; Laine, et al., 1989; Laine and Calafat, 1991; Mozammel, et al., 2002), almond shells (Rodríguez-Reinoso et al., 1982; Rodríguez-Reinoso and Molina-Sabio, 1992), olive pits (Rodríguez-Reinoso, et al., 1995); peach pits; and pecan shells (Ahmedna, et al., 2000; Shawabkeh, et al., 2001). Agricultural by-products from grain, bean, and cotton production can be used as carbon sources. These include corn cobs (McElhinney, et al., 1942; El-Hendawy, et al., 2001), oat hulls (McElhinney, et al., 1942), rice hulls, rice straw, and soybean hulls (Ahmedna, et al., 1997) are commonly available in many places. Sugar processors can produce activated carbon in-house using bagasse (Ahmedna, et al., 2000). A considerable number of alternative feedstocks are technologically feasible, but turned out to be economically unattractive (UN FAO, 1985). Sugar (sucrose) can be used to produce a high purity activated carbon (Evans, et al., 1999). Other processing by-products include coffee grounds (Giffie, 1974). Bones from organic animals could be used to make organic bone char. All of these agricultural feedstocks can be organically produced.

Similarly, many diverse tree species can be used to produce wood converted into charcoal and activated by various chemical and physical means, yielding active carbons with a wide range of characteristics and specifications (Paulssen, 1964; Mantell, 1968; Baker et al., 1992; Arriagada, et al., 1994). These can all be produced by organic agro-forestry methods, provided that forest products fall within the scope of organic standards, and processed by methods that would comply with the NOP Final Rule.

The activation process chemically changes all sources. Most methods of chemical activation involve the use of substances prohibited in organic handling. However, some of the methods to activate carbonaceous feedstocks would

comply with organic processing and handling standards. For example, because water is allowed under the NOP (7 CFR 205.301) it is possible to steam-treat rather than acid-treat the carbonaceous material to produce an activated carbons that meet most specifications (Arriagada, et al., 1994; Rodriguez-Reinoso, 1995; Burdock, 1997). Most of the atmospheric gases used to activate carbon are on the National List, including nitrogen (7 CFR 205.605(a)(12)), carbon dioxide (7 CFR 205.605(b)(8)), and oxygen (7 CFR 205.605(a)(13)).

Agricultural by-products can be chemically activated using a variety of acids and bases. One acid mentioned is acetic acid, found in vinegar; potassium hydroxide and sodium hydroxide are both mentioned as possible bases (Shawabkeh, et al., 2001). Organic acetic acid can be obtained either from organic vinegar or by destructive distillation of carbon sources as a by-product of the charcoal-making process (UN FAO, 1985). Potassium hydroxide (7 CFR 205.605(b)(27)) and sodium hydroxide (7 CFR 205.605(b)(32)) both appear on the National List. Given organic agricultural products and by-products, and nitrogen, carbon dioxide, steam, potassium hydroxide or sodium hydroxide as activating agents, activated carbon can be produced as an organic ingredient.

While four large industrial producers control over 90% of the market (Baker, et al., 1992) it is also feasible to make charcoal and activated carbon on a small scale (Karch, 1982; UN FAO, 1985) and for food processors to manufacture activated carbon from precursors generated on-site (Ahmeda, et al., 2000). Activated carbons made from agricultural by-products can perform as well as if not better than commercial sources (Ahmeda, et al., 1997).

Defatted seeds, such as soy meal, sesame seed meal, canola meal, and linseed meal can all be used to remove contaminants from water, including some contaminants not easily removed by activated charcoal (Adachi, et al., 2000).

2. *Its manufacture, use, and disposal do not have adverse effects on the environment and are done in a manner compatible with organic handling as described in section 6510 of the OFPA.*

Effect on the environment varies according to the source of carbonaceous material and the process used to activate it. Using organic agricultural sources as a baseline for comparison, the greatest adverse impact of the manufacture of activated carbon from organic agricultural by-products would be the possible removal of organic matter from the system.

A comparison of the environmental impacts of manufacturing alternative sources is beyond the scope of the current TAP review. This would involve a survey of the environmental impacts of coal mining, conventional agricultural, and petroleum production.

The environmental effects of use are generally considered beneficial. The US EPA encourages the food industry to use activated carbon to treat wastewater effluent (US EPA, 2000) and volatile and greenhouse gas air emissions (US EPA, 1995). Recycling activated carbon is generally thought of as beneficial to the environment as well, but the process of reactivation may involve the generation of a hazardous waste stream of adsorbed toxic chemicals (Shapiro, 1996). A number of activated carbon manufacturing plants are also classified as hazardous waste facilities because they are handling spent activated carbon filters that are regenerated (See, for example, Oklahoma Department of Environmental Quality, 1999).

Reuse and recycling reduces the amount of solid waste generated, but may create a hazardous waste stream, depending on what is adsorbed, how much, and in what concentrations. It is not economical or even possible to remove all contaminants in regeneration (Mine Safety Research Appliances Corp., 1970). Although regeneration techniques are improving, there are limits as to the contaminants of regenerated carbon. As long as these meet Food Chemicals Codex specifications, then the source for use as an indirect food additive or processing aid does not appear to be restricted. Various methods to simplify and improve the efficiency of regeneration mean that commercial sources are more likely to be reused and recycled (Mine Safety Research Corp., 1970; van Duijn, 1993). While the spent carbon can be regenerated, a certain amount of structural degradation takes place and after a certain point it is no longer possible to regenerate (Battelle, 1970). Combustion as fuel creates carbon monoxide and carbon dioxide. Disposal can be problematic when toxic contaminants are removed from the adsorbate. These can be considered hazardous waste, and may require special measures to handle and dispose even when below legal thresholds set for such waste. Otherwise, such compounds could contaminate food, water, and the rest of the environment.

3. *If the nutritional quality of the food is maintained and the material itself or its breakdown products do not have adverse effects on human health as defined by applicable Federal regulations.*

In some cases, nutritional quality is diminished and in other cases it is enhanced. Often there is no change. This depends on a number of complex factors: the nature of the activation of the carbon, the nutritional quality and chemical properties of the adsorbate, the preparation, and the various factors related to adsorption. In the case of the petitioned use, it appears that much of the nutritional content is lost in the process. More data on the nutritional components of the unclarified and clarified grape juice is needed. It is likely that certain nutritional components—in particular cation minerals such as calcium and iron—are lost in the clarification process, as they are with the refinement of other sugars. Activated carbon can be used to remove amino acids and carbohydrates from food as well (Mattson and Marks, 1971).

In some cases, activated carbon treatment can improve a nutritional profile by removing non-nutrient components. For example, protein levels were maintained or even slightly increased in an activated carbon treated soymilk yogurt when compared to an untreated soymilk yogurt (Lee, et al., 1990). However, the nutritional significance of differences in both directions is debatable. Similarly, the nutritional value of citrus peel juice and molasses also increased as bitter, unpalatable, and inedible components were removed by activated carbon (Grohmann, et al., 1999).

The material itself and its breakdown products do not have adverse effects on human health as defined by applicable Federal regulations. Some of the effects on human health are beneficial. Activated charcoal, along with bentonite, has been shown to reduce the amount of the mycotoxins aflatoxin in milk (Doyle, et al., 1982) and patulin in apple juice (Sands, et al., 1976; Doyle, et al., 1982).

4. *Its primary purpose is not as a preservative or used only to recreate/improve flavors, colors, textures, or nutritive value lost during processing except in the latter case as required by law.*

The petitioned use is to remove brown color from white grape juice concentrate (Canadaigua, 2002). Therefore, the primary purpose in the petition is to improve flavor and color. Many other uses of activated carbon are also related to the characteristics deemed non-compliant by this criterion. For example, activated carbon is reportedly used to remove stale flavor components found in ultrahigh temperature (UHT) processed milk (Coulibaly and Jeon, 1992).

5. *Is Generally Recognized As Safe (GRAS) by FDA when used in accordance with Good Manufacturing Practices (GMP), and contains no residues of heavy metals or other contaminants in excess of FDA tolerances.*

Carbon black obtained by the impingement or channel process ('gas black' or 'channel black') has been banned by FDA for use as a color additive in foods, drugs, and beverages (Budavari, 1996). However, the use of such sources for making activated charcoal as a processing aid is unclear. The presence of cancer-causing impurities in activated charcoal (carbon) is noted as a concern (Winter, 1989).

The Food Chemicals Codex (1996) specifications for food grade activated carbon are:

Cyanogen compounds: passes test

Heavy metals (as Pb): Not more than 0.004%

Higher aromatic hydrocarbons: Passes test

Iodine value: Not less than 400

Lead: Not more than 10 mg/kg

Water extractables: Not more than 4.0%

6. *Its use is compatible with the principles of organic handling.*

In general, organic handling and processing limits the refining of products and the use of additives and processing aids (Codex, 1999). A survey of organic processors found that most considered filtration of water through the use of activated charcoal to be acceptable (Raj, 1991). However, that same survey did not consider the use of activated charcoal for sweeteners.

7. *There is no other way to produce a similar product without its use and it is used in the minimum quantity required to achieve the process.*

It is possible to produce a concentrated grape juice without the use of activated carbon or some other ion exchange to remove color. Selection of lighter colored varieties, cold-pressing, freezing, centrifuging and enzyme treatment can all reduce or eliminate undesirable colors and flavors in grape juice (Tressler and Joslyn, 1954; Potter and Hotchkiss, 1998). Raisin syrup can be prepared with Fuller's earth and 'acid' clays as alternatives to activated carbon (Denny, 1930). Diatomaceous earth and silicon dioxide (silica gel) are both used as adsorbents and decolorizing agents in food processing (Considine and Considine, 1982). Without color and flavor specifications, it is not possible to judge the similarity of concentrate produced without activated carbon. Centrifuging and filtration are also used to clarify milk (Potter and Hotchkiss, 1998) and many other fluids in food processing (Considine and Considine, 1982).

It is also not possible to determine the ability of other filtering agents that are organically produced or on the National List. For example, activated carbon prepared from pecan nut shells has the same decolorizing effect on azo dyes as activated charcoal sold for water treatment (Young, 1996). Wine fined with baker's yeast had comparable removal of phenols to activated carbon, with a taste panel detecting no significant difference in color, flavor, and aroma (Bonilla, et al., 2001).

Proper handling and good inventory management can prevent the growth of organisms that result in mycotoxins. Ventilation and elimination of outside sources can reduce ethylene in storage facilities. Alternative chemical treatments include ozone and bacteria. Potassium permanganate is the preferred commercial means to remove ethylene (Reid, 1985).

TAP Reviewer Discussion

Reviewer 1

Environmental Effects

Overall use of activated carbon has a general positive effect on environmental effects.

Nutritional Quality

Application and use of activated carbon can improve, reduce or have no effect on the nutritional profile. This observation is further supported by Boulton et al. (1998) who found that activated carbon does not adsorb sugar or amino acid which are highly water soluble in wine. However, activated carbon has been shown to remove some vitamins, which according to the Boulton reference may effect microbiological stability of wine products.

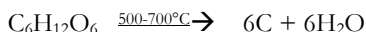
GRAS

My interpretation of the legal status of activated charcoal is that it must meet or exceed Food Chemicals Codex (1996) criteria for food grade status as required by the FDA for direct food contact as well as for pharmaceutical applications.

Compatibility

Use of activated charcoal is presently wide spread throughout the food industry for treatment of in-bound water, especially from those plants that rely on wells rather than municipal water sources. It is used to improve odor, color and/or overall sensory quality of the water as well as microbiological and therefore food safety issues. This is critical for those plants producing beverage or juice products. If activated carbon can be manufactured from agricultural products with steam or a non-synthetic chemical activation process, then I could support its limited use in organic food product systems.

However, since activated charcoal is manufactured initially by thermal decomposition according to the following reaction:



All forms of activated carbon must be considered as synthetic since its manufacture requires breakage of naturally occurring covalent bonds with concurrent chemical change to elemental carbon.

Alternatives

Activated charcoal has been used for many years to eliminate organoleptic defects in grape juice and wine. Many historical alternatives used to eliminate odor, off flavors and color such as toasted barley or wheat, mustard, oil and milk have been used in ancient enology records. Review of recent wine and enology books indicates that use of activated carbon appears to provide a more controllable, effective and perhaps cost effective approach than listed alternatives (Ribereau, 1999)

Conclusion

The literature is vast with information on activated charcoal. Use of charcoal in wine making and juice fining is very old and well documented as to overall effectiveness and modulation of controlling its desired functionality in the food or beverage system.

All forms of activated carbon should be considered synthetic even if the activation step is conducted by steam processing. Activated carbon as used and as proposed in the petition does not remain in the food product. Its residence time may vary from minutes to hours depending upon the application; therefore it should meet the definition of a processing aid not an ingredient.

I could support use of activated carbon as a processing aid which must be removed from the food product if produced from an agricultural product source with steam activation. This requirement would preclude all chemical forms of activation.

Charcoal in its present form has been used historically in a wide range of both food and medical products. Activated charcoal is presently being used in water treatment and purification systems for both sensory quality and food safety issues. Therefore I feel use of activated charcoal produced by heat and steam from agricultural products or by-products and used only as a processing aid (must be removed from the product) will minimally affect organic integrity.

If water is treated with activated carbon, does that mean that the water cannot be used for organic foods? If municipal water purification systems and onsite water treatment systems utilize activated carbon does that mean the water cannot be used for organic products even though water is not included in calculating the percent organic content of the product?

My reasoning is predicated on consistency of the review and the overall merit with respect to organic integrity.

Reviewer 2

Material and manufacturing

Activated carbon or activated charcoal are . . . used [to describe] a porous carbon manufactured by a two step method (carbonization followed by oxidation). The structure consists of a distorted three dimensional array of aromatic sheets and strips of primary hexagonal graphic crystallites (Stoeckli, 1990). This structure creates angular pores between the sheets of molecular dimensions which give rise to many of the useful absorption properties of activated carbon (Stoeckli, 1990; Innes et. al. 1989). Pore size ranges from 1 nm to 1000 nm, and the extensive porosity is responsible for the high surface area of the material—usually 500 - 1500 m²/gm. (Vohler et. al. 1986; Cooney, 1980).

Carbon black or lamp black is another carbon product with high surface area. Lamp black consists of soot from burning a carbon source (wood, tar, coal, oil, etc.) in a limited oxygen environment (Davidson et al., 1968). The high surface area and surface properties of lamp black are derived from the fine particle size of the material, not from high porosity like activated carbon. The lack of extensive porosity distinguishes activated carbon from other carbon products like lamp black or charcoal. We will consider only true activated carbon in this review and its recommendations. Charcoal and lamp black are distinct materials and should not be considered in an activated carbon tap.

Charcoal was first used medicinally in 1550 B.C Egypt and bone char has been in use since 1811 to decolorize sugar (Cooney, 1980). True activated charcoal was not invented until the beginning of the last century and activated carbon derived from coconuts was used in gas mask filters . . . World War I (Cooney, 1980).

Most any carbon material can be used to make activated carbon and the academic literature contains many references to activated carbon derived from many agricultural and industrial high-carbon waste products. Commercial activated carbon, however, is manufactured from only a few carbon sources; wood and sawdust, peat, coal, oil products, and nut shells and pits (Vohler et. al., 1986; Davidson et al., 1968). Wood products and low-grade coal have some original porosity and are easier to activate than dense materials such as anthracite (Vohler et. al., 1986; Sun et. al., 1997). However, any high carbon material can be activated, and it is generally not possible to discern the original starting material of an activated carbon product.

Activated carbon manufacturing consists of a charring or carbonization step in which the most of the non carbon material (and much of the carbon) is volatilized by pyrolysis (usually between 500 and 750° C). The weight loss is usually 60 to 70 % and much CO₂ is volatilized (Sun et. al., 1997, Diaz-Teran, 2001). Coal is usually first pre-oxidized at 150° to 250° C. to prevent the coal from becoming thermoplastic during charring and collapsing the pore structure (Sun et. al., 1997).

The fine pore structure is formed in an activation process. In gas activation, an oxidizing gas such as CO₂ is used at high temperature to erode pores into the char. In chemical activation, the char is impregnated with a chemical and then fired to high temperatures (usually 800 to 1000° C). The activating chemical corrodes the carbon to form the pore structure. Chemical activation also alters the carbon surface. Activation chemicals are usually strong acids, bases or corrosives (phosphoric acid, sulfuric acid, KOH, zinc chloride, potassium sulfide, or potassium thiocyanate) (Mozammel et. al. 2002). After activation, the chemicals are washed out for reuse. The final pore structure depends on the nature of the starting material and the activation process (Diaz-Teran, 01). Materials with an original pore structure like wood take less processing than more dense and isotropic material like coal or tar. Impurity amounts are usually higher in the less carbon dense materials, however.

The surface chemistry of the activated carbon is strongly influenced by the activation process and subsequent chemical treatment (Pradhan and Sandle, 1999). The surface contains abundant oxygen and hydrogen groups which can decompose

to CO₂ and water (Puri, 1966). Other surface oxide complexes that have been found include phenols, carbonyl, lactone, carboxylic acid, and quinones (McCreedy, 1991, Pradhan and Sandle, 1999). The abundance of surface complexes causes activated carbon to be a good absorber of many gases and aqueous chemicals. The non-selective absorption of many chemicals make activated carbon an excellent absorber in poisoning or environmental contamination (Cooney, 1980). Non-selectivity is less desirable when a specific chemical is to be removed from a process stream. Activated charcoal is impregnated with potassium carbonate for efficient catalytic reduction of CO₂ gas (Yokoyama et. al. 1979), and debittering of citrus peels is mostly accomplished through the use of ion exchange resin (Grohmann et al., 1999).

Charcoal is generally considered to be a natural agricultural product. Both charcoal and carbon black form naturally (forest fires), and have been used by man for thousands of years. Activated carbon does not occur naturally. A highly controlled two or three stage process is needed to form the high porosity of activated carbon. The activation step also requires either the addition of a synthetic chemical or direct injection of CO₂ or O₂ during the activation firing. Highly porous activated carbon should be considered synthetic. Bone char results from the destructive distillation of animal bones (Mantell, 1968; Davidson et al., 1968). Bone char production does not include an activation step. It is more analogous to the left over material in the destructive distillation of coal to make coal tar.

Interactions with other materials

Activated carbon will not have any detrimental chemical interactions with any other chemicals that would be used in Organic food processing. Activated charcoal is a mild reducing agent and a catalyst (Hoffman et. al., 1983, Diaz-Teran et. al., 2001, Pradhan, & Sanbdel, 1999), but will not react strongly with any Organically allowed substances (carbon MSDS).

Toxicity and Mode of Action

Activated carbon is generally considered non-toxic. Large doses are routinely given in human poisoning cases. The human dose for poisoning is 1 gm activated charcoal per kg. body weight (Scharman et. al., 2001, Minocha et. al., 1985).

Manufacture, Use, and Disposal

Activated carbon poses little risk of environmental contamination. If spent activated carbon were to be landfilled or applied to crop lands, any environmental contamination would come from the materials that the activated carbon filtered out of the process stream, not the activated carbon itself.

Many of the activation chemicals used to form the pore structure of activated carbon, however, are toxic. Exposure to zinc chloride fumes or solutions can cause ulceration and fatal burns (Hamilton & Hardy, 1974). These chemicals are reused and should be disposed of safely in large plants. The carbonization step removes as much as 70% wt. of the original carbon material as volatiles. 700,000 tons/yr of activated carbon were manufactured in the late nineties (Mozammel et. al., 2002). This would release almost 500,000 tons of volatiles (mostly Carbon Dioxide) to the atmosphere per year. The charring and activation processes also consume large amounts of energy (Sun et. al., 1997).

Pharmaceutical grade activated carbon requires a low amount of non-carbon components (Cooney, 1980). Almost all activated carbons (except for some from anthracite) require some amount of acid leaching to be sold as USP pharmaceutical grade. Carbon sources like wood, peat or fruit shells generally have a higher ash content than high grade coal. USP grade activated carbon must have < 15% wt drying loss and < 3.5 % acid soluble residue (Cooney, 1980). Materials with a higher initial ash content would need to be acid leached more than once with low initial ash content.

Almost any carbon source can be made into activated carbon (Vohler et. al., 1986). Without a detailed calculation, it is not obvious which sources of carbon have a lower environmental footprint. Given this lack of knowledge of the environmental costs of the different carbon sources, it would seem prudent to either allow or prohibit activated carbon from any source in organic management systems.

Activated charcoal has been shown to interfere in vitro growth of bile-tolerant *Helicobacter* bacteria—an emerging pathogen of humans and animals (Tanecar, 2002). The mechanism appears to be the absorption of chemicals toxic to the bacteria. Activated carbon has been reported to promote the growth of certain pathogenic bacteria (e.g. *Listeria monocytogenes*, and *Legionella pneumophila*) (Erolaeva, 1999, Hoffman et. al., 1983). Potential mechanisms are absorption of toxins or reduction of peroxide free radicals.

Proper sanitation during food processing should eliminate the possibility of pathogens in the food product. If contamination does occur, however, activated carbon could actually help, not hinder growth of certain pathogens.

As stated above, there is little danger from ingested activated carbon. Dust at manufacturing sites needs to be managed. There is no unique hazard associated with activated carbon dust that is not encountered with other small particle sized materials.

Interactions

Spent activated carbon could be spread on farm fields or composted with municipal organic wastes. In some processes, like decolorizing vinegar, the activated carbon is used only once (10 - 20 gms of activated charcoal per liter of vinegar) and can constitute a large waste stream (Achaerandio et. al., 2002).

Source and Substitutes

As stated above, activated carbon can be produced from almost any carbon source: including many agricultural by-products. The final properties of the activated carbon depend on the time and temperature profiles of the charring and activation steps, the gaseous redox conditions of thermal activation, and the chemical composition and powder properties of chemical activants (Vohler et. al., 1986; Sun et. al., 1997; Rodriguez-Reinoso & Molina-Sabio, 1992). The amount of ash also depends on the carbon source, with peat and plant-based precursors usually having large amounts than carbon dense materials like coal having low amounts. Higher ash contents require more vigorous acid leaching to make UPS grade activated carbon. A trade-off exists between the nature of the carbon precursor, and the amounts of energy and toxic processing chemicals used.

Restricting the precursors to plant products would shift these trade-offs to a possibly more costly, and less environmentally produced synthetic chemical. Safe handling and disposal of toxic activation and leaching chemicals is usually best carried out in large plants. Large plants would also be able to recycle or remove the large amount of CO₂ generated in the production of CO₂. Restricting the carbon sources to Organically grown plant materials would sharply raise the price of the activated carbon produced. Organic plant wastes would also be better used as soil amendments.

Acetic acid is listed as a leaching chemical for activated carbon (Shawabkeh et. al., 2001), and naturally fermented (or organic) vinegar is mentioned as a source of acetic acid. Fermented vinegar is usually 4 to 15 vol. % Acetic Acid (Ebner, 1996). Two-stage fermentation can drive the Acetic Acid content to 20 vol. % (Kunimatsu et. al., 1981). Acetic Acid contents this low should not be capable of leaching many of the activated carbon ash chemical species.

As discussed in point 7 below, there are many natural products that could clarify juices. Several of these natural materials can also be obtained from Organic sources in quantity (egg white, gelatin, and casein).

Nutritional Quality

The strengths of activated carbon as a poison antidote and water purification aid are its great absorption capacity, and its ability to absorb many chemical with different structures (Cooney, 1980). Ion exchange resins exist that are better absorbers than activated carbon for either acidic or basic chemical species, but not for neutral chemical species. Activated carbon is also equally absorbent for both ionic and neutral species and is the most universal absorbent for complex mixtures of chemicals structures (Cooney, 1980, Vohler et. al. 1986).

The petitioned use for activated carbon is to remove off color and polyphenols from white grape juice. Polyphenols such as Resveratrol, and pycnogenols are powerful antioxidants and are concentrated in grapes (Sovak, 2002; Pengelly, 1996). Activated carbon is a strong absorber of phenols (Anderson, 1946) and should be efficient in removing these tannins from grape juice. The presence of these antioxidants in grapes, however, is one of the reasons why some Natural Product/Organic consumers buy grape products (Roehl, 1996). Removal of the polyphenols lowers the value of the product as a functional food (especially if consumers become aware of the removal).

Grapes and grape juice are rich in Potassium, Calcium, Magnesium, Manganese, Phosphorus, and Vitamin B-complex (Roehl, 1996; Onstad, 1996). Activated carbon is a good absorber of B vitamins (Cooney, 1980), and cations (Vohler et. al., 1986) and should also remove some of these nutrients from food products. Although not directly relevant to grape juice, activated carbon catalyses the deamination (oxidation) of amino acids (Cooney, 1980). Phenolic amino acids are especially susceptible to destruction (Furth and Kaunitz, 1930).

Primary Purpose

The petition states that the purpose for activated carbon is to remove excess colored pigments from white grape juice which give the juice a disagreeable color and aroma (Canadaigua, 2002). This use is to improve flavor/aroma and color, and is contrary to the processing aid criteria for use established at the 10 Feb. 1999 NOSB meeting.

FDA Status

Activated carbon (CAS# 64365-11-3) is generally recognized as safe when it is acid washed and meets USP food grade status (Brudock, 1997). Allowed uses in food are as a decolorizing agent, purification agent, and as an odor or taste removing agent.

Compatibility

The intended use for activated carbon is to improve the color and aroma of processed fruit juice. It also makes all lots of juice consistent in color and flavor, blending out any distinctive characteristics of different grape varieties or growing seasons (see Achaerandio et. al. 2002 and Bonilla et. al., 2001 for discussion of creating uniformity in vinegar and sherry through the use of activated charcoal). Organic handling strives to minimize processing and enhance, not destroy distinctive characteristics of the original organically grown product. Proper growing, harvesting, transport, and crushing should help control the problems that the petitioner is experiencing with their grapes.

Alternatives

The stated use of activated carbon in the petition is to remove excess brown color from white grape juice. This use is analogous to the removal of brown color in white wine (Bonilla et. al., 2001). *[Fining is the usual way to remove]* unwanted color and suspended solids from wine. While activated charcoal can remove colors due to tannins, solids are also removed by fining agents. Fining agents employed in wine are Bentonite clay from Wyoming (Cox, 1991), or protein, *such as* egg whites, skim milk, gelatin, or casein . . . (Amerine and Singleton, 1965). These fining agents are natural products and can be obtained from organic sources. Bonilla et. al. (2001) found that spent yeast cells can decolorize white wine without removing solids. Suspended solids can also be removed by filtering.

Recommendations

Activated Carbon with high porosity and surface area is a synthetic material. It is manufactured by a complex multistep process and has no natural analog. Its ability to absorb many chemicals from gas or aqueous solution makes it an excellent filtration aid for complex solutions like water. When a specific chemical needs to be removed from a product, there are usually more efficient chemicals to use than activated carbon (Huwig et. al., 2001).

The petitioned use is to clarify and improve taste and aroma of an organic fruit beverage. The use of activated carbon to clarify the juice would remove antioxidants and minerals, lowering the nutritional value of the juice. Better fruit harvest and processing should help eliminate the need for clarification, and several natural materials could replace activated carbon in this processing step.

Conclusion

- Activated Carbon is a synthetic material;
- Activated Carbon should be placed on the National List of Allowed Synthetic;
- Processing Materials for filtering water, only. It should not be used to recreate/ improve flavors, or colors of organically processed food.

Reviewer #3

Database

The database is moderately complete. The problem with AC is that there is so much information available that it is difficult . . . to winnow it down to any reasonable volume. . . I would have like to have seen more descriptions of its uses within organic processing operations. Also, a better description of the actual commercially available product would be helpful. . .

Source and Substitutes

I would argue that, according to current standards, the original process of producing and activating charcoal is non-synthetic burning. Carbonaceous products are burnt in a reduction atmosphere, and are not reduced completely to ash, but the process is simply interrupted; it is a naturally occurring process, and the burning of wood or other [agricultural by-products] to ash is acceptable within the current organic parameters. Activation by further burning with the addition of steam is a continuation of that process; there are no significant changes in the chemical reaction caused by pyrolysis. Temperatures are closely controlled. Although CO₂ and N₂ are also used as treatments, I think the “natural” definition could be stretched to include those; they do not change the actual reaction during the pyrolysis, they do cause more consistency, and help to provide an atmosphere in which charcoal can “micro-burn” to produce the desired porosity.

The process can *[cause synthetic reactions]* in 2 ways:

1. The pyrolysis of prohibited materials. Source materials such as lignite, coal tars, and plastics are prohibited or restricted for use in organic processing. Although the final product is carbon and ash, there are some precedents (composting and fermentation media byproducts, for instance) in which prohibited feedstocks are not allowed, even though the final product may be indistinguishable from its counterpart made with allowed feedstocks.

2. The addition of some chemical treatments such prohibited salts, acids and bases. These substances can be added to the charred material before the final heating process. These additions allow the final heat process to be performed at a lower temperature, as well as affecting the polarity of the final product. The final step in this process may be rinsing and recovering the chemical treatments.

As far as I've been able to tell in my reading, the goal of these chemical additions is the same as the steam/CO₂/N treatments, that is, to produce meso- and micro-pores, and to produce specific pore sizes. The functions of pH or specific polarities appear to be secondary to producing appropriate pore sizes. Treatment to influence these characteristics may occur during any step of the process, although it appears that the majority of treatment is done before the second pyrolysis. However, as many of the chemical treatments appear to act as catalysts by lowering the reaction temperature that produces the meso- and micropores, this process must be defined as synthetic, according to our current standards, even if all of the chemicals are on the approved list.

The main difficulties with defining activated charcoal as non-synthetic are that:

1. Different source materials and treatments produce different adsorption characteristics, and different qualities of activated charcoal (for instance coconut shell makes very high quality activated charcoal, where sugar cane makes both lower quality activated charcoal, and a smaller percentage of finished product).
2. Manufacturers mix activated charcoals from a variety of sources to produce specific predictable qualities, and to control pricing.

The processor/buyer has little, if any control over what charcoal sources are actually in his specific product, and would be mostly concerned with whether or not the charcoal provides the effects he requires, and does so at a reasonable price.

I originally looked at the different classes of activated charcoal, and decided that the simply processed material (pyrolysis and steam) could be described as non-synthetic. However, since there is no good way to differentiate between the classes, and the product as it currently stands (mixed from various sources) is in common use, then it might be more advisable to simply include all classes under one title and declare it synthetic.

Finally, I would suggest some research into whether or not AC's could be divided as non-synthetic (allowed base materials, treatments with allowed acids, salts and bases (HoAC, NaOH, KOH) steam or atmospheric treatments during pyrolysis) and synthetic (prohibited materials, treatments with prohibited acids and bases). If a clean differentiation can be made between the two, and if the industry can purchase AC's that meet our criteria for non-synthetic, then I think that the rule should be written in such a manner that allows the unrestricted use of the non-synthetic class of AC. A transition time period might be needed to allow an orderly transition from the current mixed grades of charcoal to a totally non-synthetic paradigm.

The above is assuming that the AC's are coming into direct contact with food.

AC's used as processing water treatment and waste stream treatments could be treated differently; different types of treatments and charcoal types may be necessary to treat the anticipated impurities from these sources. A list of compounds and their compatibility with AC cleanup methods is included. (Barnebey and Sutcliffe).

AC could adsorb enough materials to be considered hazardous waste. How would that be known? How is activated carbon known to be exhausted? Other ion exchange products often have indicators that change color when the material is exhausted. Incineration would be the obvious choice for disposal, with composting another option, or spreading on farmland. This would, of course, assume that the AC does not have hazardous quantities of adsorbate.

Manufacture, Use, and Disposal

AC production appears to be a fairly simple and straightforward process. Any VOC's and particulates can be easily scrubbed, and about the only output to the atmosphere would be CO₂. Disposal should be fairly unproblematic. In many cases the acids, bases and salts are recovered and re-used. Where disposal is necessary, it can be achieved in an environmentally sound way with little effort.

Compared with the production of other (plastic-based) ion exchange resins, this product seems to be far the lesser of the evils.

Disposal could be another issue, especially when considered in the context of waste stream treatment. When used to adsorb hazardous substances, AC would concentrate these compounds, and could become hazardous waste.

Nutritional Quality

Activated charcoal is used medicinally to adsorb a wide variety of toxins. If trace quantities of the charcoal are left behind, it is basically nothing but carbon, and ash (metallic elements), which could be in solution in acid medias such as juices. It may be that the carbon has high enough activity that the metals aren't released in typical food-grade acid environments. Heavy metals content of AC's may be of interest when it comes in direct contact with food.

Primary Purpose

Its primary purpose is to remove perceived impurities, including colorants, chemicals that can produce off-flavors, compounds that can change product quality during storage. I'm not entirely sure that all of these are consistent with "minimum processing" goals, however, this is a subtractive process, not an additive one. No flavors, preservatives or nutritional properties are added. There may be some preservative effects from removing some of the oxidizing materials that cause browning or off-flavors, but a preservative as such is not added.

FDA Status

When used in an appropriate fashion, AC as a class is considered GRAS. There doesn't seem to be any differentiation between the different types of AC.

Some uses and limits:

- *sugar cane and sugar beets;
- *white grape juice for fructose manufacture;
- *sugar cane juice for "less refined" sucrose manufacture;
- *fats and oils;
- *wine (0.9% limit);
- *sherries (0.25%);
- *red and black grape juices (0.4%);
- *patulin removal in apple juice;
- *aflatoxin removal from juices;
- * removal of anthoquinones from aloe vera juice;

Alternatives

If activated charcoal were disallowed, it would certainly affect the organic sweetener industry in a big way.

Conclusions

1. Activated charcoal duplicates or exceeds the function of many other more specialized ion exchange resins (Supelco bulletin #846D) with fewer complex issues in terms of manufacture, use and disposal.
2. Activated charcoal in its most basic form (pyrolysis and steam/CO₂/N₂ treatment) could be considered non-synthetic/allowed.
3. Treatment with specific compounds lowers the final pyrolysis temperature and polarizes the charcoal to attract specific compounds. If the original process is considered non-synthetic, and the subsequent treatments are done with approved materials, it seems that the product would be acceptable as a synthetic/allowed.
4. The production of activated charcoal from prohibited feedstocks and/or treatment with prohibited chemicals may render this type of AC synthetic/prohibited, or synthetic/restricted to uses not in direct contact with food
5. If AC must be treated as a single class, it should be considered synthetic
6. Several industries would be hard-pressed to continue organic production without some kind of purification aid, and activated charcoal appears to fit their needs.
7. Disposal methods of spent charcoal should be examined.

**The TAP Reviewers were also asked the following questions
(see reviews for individual responses):**

General

I.. Sources and Manufacturing Processes

Activated charcoal can be made from almost any carbonaceous material.

1. Are any sources non-synthetic or are they all synthetic?
2. If some are non-synthetic, please indicate or specify criteria to determine what methods and processes make a 'natural' activated charcoal.

Note: while the NOP definition of synthetic includes anything chemically changed from a naturally occurring source, NOSB has historically clarified this and followed the policy that heating and combustion of plants, animals and microorganism is not synthetic, while combustion of minerals is synthetic. (1995- Definition and Interpretations).

3. Do you think charcoal could be considered an agricultural product?
 - a. If so, do you agree that it is feasible to produce activated charcoal that meets National Organic Program standards for being an organic agricultural product?
 - b. Under what circumstances should non-organic activated charcoal be allowed?
 - c. If not, do you consider all sources non-agricultural?
4. Is it correct to state that the FDA allows activated carbon from any source, provided that it meets food grade (FCC) specifications (as a processing aid) or pharmaceutical (USP) specifications as an animal drug?

II. Action

5. Is surface oxidation a redox reaction? Can you briefly explain the mechanism and give an example of how that might work with the removal of a non-polar substance from solution?

III. For Food Processing

1. Are there any legal source restrictions on activated charcoal? It appears that fossil sources and spent ion-exchange polymers are both used commercially in food processing. While the sewage sludge sources appear to be used to treat effluent, is there any law to prevent its use in, say, decoloring sugar?
2. What is the nutritional quality of the unclarified and the clarified grape juice? In particular, does the refinement process remove any nutrient minerals, vitamins, or proteins?
3. In general, highly processed foods like refined sugars have not been considered 'compatible with principles of organic processing.' This is reflected in various standards documents such as the IFOAM *Basic Standards* and Codex Alimentarius. Do you have any consumer surveys that indicate consumer preferences for refined v. unrefined products?

Conclusion:

Activated carbon is generally considered non-agricultural and synthetic, even if it is conceivably possible to produce activated carbon that meets National Organic Program Standards for production and handling. The reviewers all favor allowing the use of activated carbon, although all recognized that restrictions on sources and / or uses might be appropriate, either immediately or phased in over time. It is widely used to perform ion exchange, and is used for refining sugar and other sweeteners. The NOSB may want to discuss the recommendation of annotations that would the most desirable sources and manufacturing processes out of environmental consideration, a long-term program to encourage production and processing of activated carbon from agricultural sources that meets the National Organic Program standards, and the compatibility of its use to process highly refined foods.

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